

THE IMPACT OF ON-LINE TESTING IN THE BLOW MOULDING PROCESS

Robin Enderby, Chairman, Blow Moulding Controls Ltd, UK

There is a famous scene in *The Graduate* where a well-wisher takes Dustin Hoffman aside and says, 'I just wanna say one word to you. Just one word.' Most people remember that the word was 'Plastics'. Not so many people remember Hoffman's reply of 'Exactly how do you mean?'. In its air of bafflement tinged with suspicion the phrase could well serve for all of us plastics people at one time or another.

This afternoon, in pursuit of exactly how do we mean about on-line testing I am going to offer you not one word but just two letters; P Y. P Y is not a radio station, neither is it a brand of gum or an obscure airport, but it may be the answer to Murphy's law. P Y stands for Poka Yoke and the words mean 'mistake proofing'.

Murphy's law holds that if a thing *can* be done wrong then sooner or later it *will* be. Poka Yoke is about designing systems so that things can't be done wrongly. It is about accepting that mistakes will be made, and designing the process to head them off at the pass or at least detect them at the earliest possible stage. The idea is to prevent mistakes turning into defects and above all, to prevent defective parts reaching the customer. There are three main

planks in the Poka Yoke platform. First, you should not be able to perform a process if any of the conditions are wrong. Second, work should not be able to move on until a process has been fully performed. Third, the next process should not be able to accept the work unless the previous stage was flawless. In other words, Poka Yoke systems not only inspect but on finding a defect they also inform and demand action. This is action feedback and it is for mistake control. It is not to be confused with data feedback which is for process control.

Just to illustrate the point, let's consider two examples. If an operative loads an in-mould labeller with the wrong labels, that's a mistake. A Poka Yoke system would 'key' the label to some unique feature of the mould/machine setup. This is not so easy because one mould may serve many customers, and one label shape with different graphics may serve many products. Perhaps the label barcode could be read and compared with a control barcode set by a supervisor. If the codes do not agree, signals to the labeller are interrupted and the process cannot run. The Poka Yoke system ensures that the mistake of loading the wrong labels does not produce the defect of bottles with the wrong labels. The mistake is detected at source, not inspected out later.

For our second example, imagine a blow moulder that is properly set up and producing good mouldings. After a while, excessive tail flash develops. It could be detected by the operator, or by measurements of weight or length.

Either way, there has been no mistake but there has been process drift. The observation of excessive tail flash can be used to correct the process by manual intervention or by feedback to a relevant machine control. That's process control.

What I am proposing to you is that on-line testing of blow mouldings can and should take in both process control and mistake control. In my company, we are working towards this ideal. In other words, testing should not just be a matter of sorting the bad mouldings. It is an opportunity to correct the process and the procedure. So don't just sort. Sort it out!

First, a statement of the obvious. The blow moulding process makes hollow objects. These have evident attractions as containers, and a high proportion of the world's liquid food and beverage, household, medical, personal care and industrial products now ship in blow moulded bottles, drums, tanks and containers. It is big business. In Western Europe alone, blow moulding currently consumes about 2½ million tonnes of polymer per year. These materials are converted into products with a value to the blow moulding industry somewhere in the region of 10 billion dollars.

Gardeners like to say that a weed is a plant in the wrong place. By the same token, a liquid product in the wrong place is one hell of a mess at the very best. It may also be corrosive, a health hazard, or a fire risk. The only

thing that stands between a product and the wrong place is the integrity of the container. That's why leak testing is so important in blow moulding. Never more so, in fact. Consumers expect to be protected as never before and they are ever more litigious if they think they have been shortchanged. At the same time, blow moulding costs rise and competitive pressures intensify. The response of the package designer is to sail ever closer to the wind. Containers now are thinner and lighter to an extent undreamed of just a few years ago. Products that are packed in their millions need an effective leak rate of nil in transit, in store and on the shelves. That makes efficient, economical leak testing an absolute must.

My company takes leak testing as the centrepiece of on-line testing but to it we aim to add functions and value, to improve the technology, and to build in process and mistake control. Let's look at some of the issues that arise.

First, take leak testing itself. There are a number of ways of doing this - visual inspection, underwater bubble tracing, tracer gas, tracer noise, pressure decay. They all have their pros and cons. To an extent, it is horses for courses but it has to be said that some of these methods are decidedly heavy on the cons. To this lineup we have added the new and patented technology of plasma leak testing. The technique is already in commercial use and development continues to adapt it to containers of different shapes and sizes. Plasma leak testing has three big advantages. It is independent of the container volume, it

places no mechanical stress on the container, and it detects very small holes. The smallest hole found so far is just 23 microns. Conventional methods can detect holes as small as 100 microns (or 19 times greater in area) but the test time often exceeds the blow moulding cycle.

Plasma testing depends on the electrical insulating properties of thermoplastics. A probe inserted through the container neck generates a very high charge of about 90,000 volts at its tip, causing a plasma field to coat the inner surface. A perfect container responds rather like a capacitor but any leak will induce a small but detectable tell-tale current. Plasma leak testing is proving especially effective for big supported containers such as drum liners, and for delicate objects that would be distorted by pressure testing.

While plasma leak testing shows great promise, the mainstay of on-line leak testing remains the pressure decay method. The principle is simple and well known. The container is sealed at the neck by a plug through which a pressurised gas, usually air, is passed. The container is held under pressure for a fixed test interval while a pressure sensor monitors internal pressure [*Figure 1*]. A perfect container (and test system) will show no drop in pressure over the test period but a faulty container will be betrayed by a pressure drop. As always, imperfections in the system will create noise in the signal [*Figure 2*]. Nevertheless, pressure decay leak testing is simple and robust, and has a proven ability to produce satisfactory leak detection levels over a very wide

range of blow moulded products. Furthermore, it is relatively simple to bring the process on-line by inserting it in the output conveyor line from the blow moulder. Signals from the pressure transducer pass to a controller where they are compared with preset target values. An out-of-limits pressure drop generates a command signal which triggers a diverter mechanism of some kind to remove the faulty container from the output line.

Earlier, I talked about adding functions or adding value to on-line testing. We call it leak testing plus. The idea is this. You have to test for leaks anyway, so why not take the opportunity to make other checks at the same time, instead of passing the container on for visual inspection. Advances in microprocessor technology coupled with ongoing miniaturisation of sensors and actuators mean that it is now becoming feasible to pack far more functions into virtually the same test package, and to do this in a modular manner so that the test package can be configured to suit the individual client. The microprocessor that controls the leak tester can also store and process signals from the other function units. The result is a degree of integration and economy that cannot be achieved with separate stand-alone function units.

A few examples. The pressure decay test head can be coupled with a plug probe for detecting blocked or misshapen neck bores that would foul automatic filling lines. If the plug fails to pass through the neck, it triggers a proximity sensor whose signal motivates the diverter mechanism [*Figure 3*].

Handled containers are usually asymmetrical and need to be aligned on the conveyor so that the neck is consistently presented directly beneath the pressure decay test head. That means that the handle is always presented in the same alignment so it becomes feasible to apply a photocell detector to check whether flash is present in the handle aperture [*Figure 4*].

Many opaque containers such as oil cans now include a coextruded transparent 'visi-stripe' that allows the user to see the level of the remaining contents. The presence of the visi-stripe can be checked on-line by an infrared receiver that is passed into the container as an extension of the pressure decay test head. It is easy to see how this could be combined with the blocked neck bore check. The infrared receiver confirms the visi-stripe by receiving signals from a fixed external infrared emitter [*Figure 5*]. Absent or attenuated signals proclaim a missing or defective visi-stripe.

The toplod strength of a blow moulded container is a vital indicator of its stacking performance. The pressure decay test head already has to be brought to bear on the neck with sufficient force to form a seal. The action can easily be modified to provide a controlled toplod force and an associated linear transducer can determine whether the bottle collapse is in or out of limits [*Figure 6*].

On-machine colouring by masterbatch or other means is widely used in blow moulding. Variations in the feed rate of the colour component can bring about changes in shade and of course, it is always possible to make gross mistakes like loading entirely the wrong colour. With the container consistently presented at a pressure decay test station, it is a relatively easy matter to make a non-contact colour check that could also be extended to gloss-level measurement [Figure 7]. In much the same way, non-contact temperature measurements could be taken by an infrared temperature sensor [Figure 8].

Container weight is a prime indicator of blow moulded part quality and process consistency. And needless to say, it has a very direct bearing on the processor's bottom line. On-line weighing can be set up alongside and linked to a pressure decay leak testing station that incorporates any or all of the value added testing functions. When a photocell senses the presence of a container, a vacuum-grip transfer device shifts it from the conveyor to a load cell weighing platform. The platform can be decoupled from the conveyor if vibrations are a problem. In any case, the weight measurement can be delayed by a preset time that allows the platform to settle after the arrival of the container. Signals from the platform's load cell pass to the leak tester microprocessor where the container weight is determined [Figure 9]. A good load cell can resolve to 1 part in 1,000 but system 'noise' and cell safety factors reduce the practical attainable accuracy in many cases to about 0.5gm. The microprocessor can

compare the measured weight against upper and lower limits set by the user. Out-of-limit signals can then be used to divert the container or to activate alarm signals.

That's the 'dumb' way of doing it. By dumb, I mean that the tester tells you only that something is wrong but does not help you to put it right. That's where data feed back and process control comes in. In the extrusion blow moulding process, part weight is directly dependent on parison weight and parison weight depends upon the die gap. Virtually all extrusion blow moulding machines are now fitted with die gap control by means of a linear transducer monitor and it is this that gives the opportunity to build a weight control feedback loop *[Figure 10]*.

Let's look at this proposition in more detail. The way we do it is the subject of another patent application. To be truly effective, the feedback control system has to have virtually universal machine compatibility coupled with an easy retro-fit characteristic.

A conventional extrusion blow moulding machine is equipped with parison thickness control by means of an analogue hydraulic servovalve that moves a tapered die mandrel axially so that the die gap increases or decreases. The servovalve responds to user settings which are stored in the controller and

compared against mandrel position feedback signals from a linear transducer [Figure 11].

Any variation of the feedback signal results in a corresponding correction from the controller. For automatic weight control, we hijack this effect by intercepting the signal from the linear transducer and feeding it through a signal-processing interface consisting of a unity gain amplifier with a level-shifting capability. The interface receives signals from the automatic weighing device and uses these to shift or adjust the linear transducer signal that is passing to the parison thickness controller [Figure 12].

There is a time lag to be accounted for. The latest weight signal comes from a container that was made on the preceding machine cycle. The compensation is made in two ways. First, the target weight is compared not to the latest weight but to the average weight. Containers that are far off limits will not be computed into the average. These are often one-off rogue mouldings affected by unusual external sources. And second, the correction signals are processed in an integrator which gives a convergence on the target weight. The two techniques together give a stable system free of 'hunting' effects. The allowable correction in any one cycle can be preset as a 'deadband'. The integrator is provided with a memory circuit so that a correction factor is available immediately on start up or directly after a temporary break in production [Figure 13].

In the past, weight control feedback has been attempted with electro-mechanical systems but these suffer from poor response times and limited accuracy. By contrast, the solid state signal-processing interface displays no measurable hysteresis, has no threshold value, and has a virtually instantaneous response. And of course, with data acquisition and control under microprocessor command, management information and statistics are a breeze. The weighing system has an in-built dot matrix printer as well as a standard computer interface. Standard stats include numbers tested, passed and failed, mean weight and standard deviation. The data records form a quality audit trail that can be linked to material batches, shift patterns or any other factor.

Parison thickness and therefore container weight varies throughout a production run because of variations in the process, limitations in the controls, and changes in the material input and the process environment [Figure 14]. The process in other words, is under imperfect control. Alas, perfect control is forever beyond our reach but automatic closed-loop weight control minimises a major source of variation and so has the effect of shrinking overall process variation within narrower limits [Figure 15]. This has an immediate and marked effect on quality and uniformity, and impacts powerfully if indirectly on the bottom line. But there is one effect that goes straight to profit. Because automatic closed-loop weight control confines process variations to much narrower limits, it becomes feasible to set the target weight not in mid-band

but towards the lower limit [Figure 16]. In the competitive container world the savings in materials will be very significant, especially as polymer prices rise and rise again.

This has been a tour around one company's philosophy of on-line testing for blow mouldings. The proposition is this. Testing that only tells you something is wrong amounts to nothing more than sorting. It is sticking plaster when what you need is surgery. Tests should at least tell you the nature if not the cause of the fault and whether it is occurring with unusual frequency. For most applications, 100% leak testing is *de rigueur* but we also say that it makes no sense to automate leak testing then check for everything else manually down the line. This is especially true when you can combine tests and share microprocessor control. Apart from the incremental cost of acquisition, such tests are effectively performed for free. We also say that test data should be used to correct the fault by process control or, Poka Yoke style, to prevent further production until the fault is fixed. For example, the on-line handle flash detector could prevent the blow moulding machine from cycling until the flash punch is fixed. We have demonstrated closed-loop process control by using automatic on-line weighing continually to trim and adjust parison thickness. This technique can be extended to any test result that has a demonstrable relationship with a process control. To complete the picture, we say that process control systems should be easily retro-fitted and be near

universal in scope, and that test systems should be modular and be easily adjustable in situ for a wide variety of products.

If we can achieve all that, maybe the rest of the quotation from The Graduate will come true. When Ben (Dustin Hoffman) said, 'Exactly how do you mean?', the well-wisher replied,

'There's a great future in plastics. Think about it. Will you think about it?'

'Yes I will', said Ben.